APPARATUS AND METHOD FOR EMBEDDING WATERMARK INFORMATION IN COMPRESSED IMAGE DATA, AND APPARATUS AND METHOD FOR RETRIEVING WATERMARK INFORMATION FROM COMPRESSED IMAGE DATA HAVING WATERMARK INFORMATION EMBEDDED THEREIN

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to an information embedding apparatus, an information embedding method, an information retrieving apparatus, and an information retrieving method. More specifically, the present invention relates to an apparatus and method for embedding information such as sound information and copyright information (watermark information) in compressed image data, and an apparatus and method for retrieving watermark information from compressed image data having watermark information embedded therein.

Description of the Background Art

Recently, the digital watermarking technology is increasingly studied in order to protect the copyrights of the multimedia contents such as images and music. The digital watermarking technology is the technology of confidentially recording (embedding) other information such as copyright information (watermark information) in the multimedia contents such as images and music in order to

prevent illegal copying and unauthorized use. Particularly for the image data, there is the technology of embedding sound information as watermark information so that the user can enjoy both image and sound when reproducing the media, in addition to the technology of embedding copyright information for the purpose of regulating such illegal copying and unauthorized use.

Information such as copyright information and sound information (watermark information) is embedded in image data that has already been compressed in a JPEG (Joint Photographic Experts Group) or MPEG (Motion Picture Experts Group) format by using an information embedding apparatus as shown in FIG. **31**. This operation is conducted as follows: first, the compressed image data is subjected to variable length decoding operation and run length decoding operation by a variable length decoding section **311** and a run length decoding section **312**, respectively, to extract a DCT (Discrete Cosine Transform) coefficient. The DCT coefficient thus extracted is temporarily stored in a coefficient memory **313**. An embedding section **314** then embeds watermark information in a bit of the DCT coefficient stored in the coefficient memory **313** based on bit designation information. The DCT coefficient having the watermark information embedded therein is then subjected to run length encoding operation and variable length encoding operation in a run length

encoding section **315** and a variable length encoding section **316**, respectively. The watermark information is thus embedded in the compressed image data.

As described above, in order to embed watermark information in image data that has already been compressed in a JPEG or MPEG format, the compressed image data is subjected to operations such as variable length decoding, run length decoding, embedding of the watermark information, run length encoding and variable length encoding. However, the information embedding apparatus of FIG. **31** uses a common code table **317** for the variable length encoding operation and the variable length decoding operation, and therefore cannot conduct these operations simultaneously. Accordingly, the DCT coefficient obtained by the variable length decoding operation and the run length decoding operation is temporarily stored in the coefficient memory **313**. In this way, the variable length decoding operation of the compressed image data and the variable length encoding operation of the data having the watermark information embedded therein are conducted in a time-sharing manner.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an information embedding apparatus and a method thereof which are capable of rapidly embedding watermark information in

compressed image data.

According to one aspect of the present invention, an apparatus for embedding watermark information in image data compressed by orthogonal transformation, quantization, run length encoding and variable length encoding includes a variable length decoding means, an embedding means, and a connecting means. The variable length decoding means extracts a codeword and an additional bit or bits corresponding to the codeword from the compressed image data based on a code table. The embedding means embeds watermark information in a prescribed bit of the additional bits extracted by the variable length decoding means. The connecting means connects the additional bits having the watermark information embedded therein by the embedding means with the codeword extracted by the variable length decoding means to produce a variable length code.

The above information embedding apparatus extracts a codeword and an additional bit(s) from the compressed image data and embeds watermark information in a prescribed bit of the extracted additional bits. Accordingly, unlike the conventional information embedding apparatus that embeds watermark information in a prescribed bit of a quantized coefficient (e.g., a DCT coefficient), the above information embedding apparatus does not require the run length decoding operation for extracting a quantized coefficient. Moreover,

since the watermark information is embedded in the prescribed bit of the additional bits, the codeword and the additional-bit length will not change before and after embedding the watermark information. Accordingly, unlike the conventional information embedding apparatus, the above information embedding apparatus does not require variable length encoding operation after embedding the watermark information.

Since the above information embedding apparatus embeds the watermark information in the prescribed bit of the additional bits, it requires neither run length decoding/encoding operations nor variable length encoding operation. This simplifies the overall structure as compared to the conventional information embedding apparatus.

Moreover, since the variable length encoding operation is not required, the variable length decoding operation of the compressed image data and the variable length encoding operation of the data having the watermark information embedded therein need not be conducted in a time-sharing manner. Accordingly, the above information embedding apparatus is capable of embedding the watermark information in the compressed image data at a higher speed as compared to the conventional apparatus. This enables high-speed processing in the low-frequency operation, allowing for reduced power consumption.

Preferably, the above information embedding apparatus

further includes a domain determining means. The domain determining means determines whether the codeword extracted by the variable length decoding means is included in a first frequency domain or not. The embedding means embeds the watermark information in the prescribed bit of the additional bits corresponding to the codeword determined as being included in the first frequency domain by the domain determining means.

The image having watermark information embedded therein normally has degraded quality as compared to the original image. However, the human eyes are sensitive to a change in low frequency components, but insensitive to a change in high frequency components.

The above information embedding apparatus is capable of embedding the watermark information in the additional bits corresponding to the codeword included in the first frequency domain. Accordingly, in order to prevent degradation in image quality resulting from embedding of the watermark information from being perceived, a relatively high frequency domain is applied as the first frequency domain. In contrast, for the image that cannot be viewed until license fee is paid, the watermark information is intentionally presented to the unauthorized user in a visual form. In this case, a relatively low frequency domain is applied as the first frequency domain. In this way, the watermark information can

be embedded in an appropriate frequency domain according to applications and purposes.

Preferably, the above information embedding apparatus further includes a bit length determining means. The bit length determining means determines whether the additional bits extracted by the variable length decoding means have a prescribed bit length or not. The embedding means embeds the watermark information in the prescribed bit of the additional bits determined as having the prescribed bit length by the bit length determining means.

The number of codewords included in the compressed image data varies between individual images. If a relatively large amount of data is to be embedded as the watermark information, the watermark information must be embedded in the additional bits corresponding to all the codewords included in the compressed image data. However, if a relatively small amount of data is to be embedded as the watermark information, the watermark information need not necessarily be embedded in the additional bits corresponding to all the codewords. In other words, the watermark information need only be embedded in the additional bit(s) corresponding to one or more of the codewords. Degradation in image quality is less likely to be perceived when the watermark information is embedded only in the additional bit(s) corresponding to a less frequently occurring codeword (i.e., a codeword that is included in the

compressed image data at a lower rate) than when the watermark information is embedded only in the additional bit(s) corresponding to a frequently occurring codeword (i.e., a codeword that is included in the compressed image data at a higher rate).

Normally, a quantized coefficient having a greater value occurs less frequently. Moreover, a greater group number is assigned to a greater quantized coefficient (i.e., a less frequently occurring quantized coefficient). Moreover, a greater additional-bit length is assigned to a greater group number. Accordingly, a greater additional-bit length is assigned to a less frequently occurring quantized coefficient. Moreover, a greater codeword length (code length) is assigned to a greater group number. In other words, a less frequently occurring codeword (i.e., a codeword that is included in the compressed image data at a lower rate) corresponds to a greater group number and a greater additional-bit length.

The above information embedding apparatus embeds the watermark information in the additional bits having a prescribed bit length. Accordingly, when a relatively small amount of data is to be embedded as the watermark information, the watermark information is embedded in the additional bits having a relatively long bit length (i.e., less frequently occurring bits). In this case, the locations where the watermark information is embedded are dispersed on the screen.

As a result, degradation in image quality is less likely to be perceived. In this way, the watermark information can be embedded in the additional bits having an appropriate bit length according to applications and purposes.

Preferably, the above information embedding apparatus further includes a color component determining means. The color component determining means determines whether a color component of the codeword extracted by the variable length decoding means is a prescribed color component or not. The embedding means embeds the watermark information in the prescribed bit of the additional bits corresponding to the codeword determined as being the prescribed color component by the color component determining means.

Normally, the image having the watermark information embedded therein has degraded quality as compared to the original image. However, the human eyes are sensitive to a change in luminance component, but insensitive to a change in chrominance component.

The above information embedding apparatus is capable of embedding watermark information in the additional bit(s) corresponding to the codeword of the prescribed color component. For example, in order to prevent degradation in image quality resulting from embedding of the watermark information from being perceived, watermark information is embedded in the additional bit(s) corresponding to the

codeword of the chrominance component. This suppresses the influence of degradation in image quality. In this way, the watermark information can be embedded in the additional bit(s) corresponding to the codeword of an appropriate color component according to applications and purposes.

Preferably, the variable length decoding means further extracts a codeword from the compressed image data based on the code table as preprocessing of the extracting operation. The above information embedding apparatus further includes a codeword counter. The codeword counter counts the number of codewords extracted by the variable length decoding means as the preprocessing.

In the above information embedding apparatus, the variable length decoding means first sequentially extracts the codewords from the compressed image data as the preprocessing. The codeword counter then counts the number of extracted codewords. This makes it possible to know the number of codewords included in the compressed image data in advance.

Preferably, the above information embedding apparatus further includes a bit designating means. The bit designating means designates the prescribed bit for embedding the watermark information, based on the number of codewords counted by the codeword counter.

The above information embedding apparatus designates the

prescribed bit for embedding the watermark information based on the number of codewords counted by the codeword counter, and embeds the watermark information in the designated bit. This prevents the embedding operation from being conducted again. Moreover, this enables the watermark information to be embedded uniformly so as to prevent degradation in image quality from being perceived as much as possible.

Preferably, the variable length decoding means further extracts a codeword from the compressed image data based on the code table as preprocessing of the extracting operation. The domain determining means further determines whether the codeword extracted by the variable length decoding means in the preprocessing is included in a second frequency domain or not. The above information embedding apparatus further includes a domain codeword counter. The domain codeword counter counts the number of codewords determined as being included in the second frequency domain by the domain determining means.

In the above information embedding apparatus, the variable length decoding means first sequentially extracts the codewords from the compressed image data as the preprocessing. The domain determining means then determines whether the codeword extracted in the preprocessing is included in the second frequency domain or not. The domain codeword counter thus counts the number of codewords

determined as being included in the second frequency domain. This makes it possible to know in advance the number of codewords included in the second frequency domain out of the codewords included in the compressed image data.

Preferably, the above information embedding apparatus further includes a frequency domain designating means. The frequency domain designating means designates the first frequency domain based on the number of codewords counted by the domain codeword counter.

The above information embedding apparatus designates the first frequency domain based on the number of codewords counted by the domain codeword counter, and embeds the watermark information in the prescribed bit of the additional bit(s) corresponding to the codeword included in the designated first frequency domain. This prevents the embedding operation from being conducted again.

Preferably, the above information embedding apparatus further includes a header information producing means and a multiplexing means. The header information producing means produces header information that indicates which of the additional bits has the watermark information embedded therein. The multiplexing means multiplexes the header information produced by the header information producing means with the variable length code produced by the connecting means.

The above information embedding apparatus multiplexes the header information that indicates which of the additional bits has the watermark information embedded therein. Accordingly, when the image is restored, the embedded watermark information can be correctly retrieved by analyzing the header information.

Preferably, the above information embedding apparatus further includes a header information producing means and a multiplexing means. The header information producing means produces header information that indicates a frequency domain of the additional bit having the watermark information embedded therein by the embedding means. The multiplexing means multiplexes the header information produced by the header information producing means with the variable length code produced by the connecting means.

The above information embedding apparatus multiplexes the header information that indicates a frequency domain of the additional bit having the watermark information embedded therein. Accordingly, when the image is restored, the embedded watermark information can be correctly retrieved by analyzing the header information.

According to another aspect of the present invention, an apparatus for retrieving watermark information from compressed image data having watermark information embedded therein by the above information embedding apparatus includes

an analyzing means, a variable length decoding means, and a retrieving means. The analyzing means recognizes the prescribed bit having the watermark information embedded therein, based on the header information. The variable length decoding means extracts an additional bit or bits from the compressed image data based on a code table. The retrieving means retrieves data of the prescribed bit recognized by the analyzing means from the additional bits extracted by the variable length decoding means.

The above information retrieving apparatus retrieves watermark information from the compressed image data having the watermark information embedded by the above information embedding apparatus. This compressed image data has header information multiplexed therein. The header information indicates which of the additional bits has the watermark information embedded therein. The bit having the watermark information embedded therein is recognized based on the header information. The data of the recognized bit is then retrieved from the additional bits extracted by the variable length decoding means. In this way, the above information retrieving apparatus recognizes the prescribed bit having the watermark information embedded therein based on the header information, and retrieves the data of the recognized prescribed bit from the additional bits extracted by the variable length decoding means. This enables the embedded

watermark information to be retrieved correctly.

According to still another aspect of the present invention, an apparatus for retrieving watermark information from compressed image data having watermark information embedded therein by the above information embedding apparatus includes an analyzing means, a variable length decoding means, and a retrieving means. The analyzing means recognizes a frequency domain of an additional bit having the watermark information embedded therein, based on the header information. The variable length decoding means extracts an additional bit or bits from the compressed image data based on a code table. The retrieving means retrieves data of the prescribed bit of the additional bits extracted by the variable length decoding means when the extracted additional bits are included in the frequency domain recognized by the analyzing means.

The above information retrieving apparatus retrieves watermark information from the compressed image data having the watermark information embedded by the above information embedding apparatus. This compressed image data has header information multiplexed therein. The header information indicates a frequency domain of an additional bit having the watermark information embedded therein. The frequency domain of the additional bit having the watermark information embedded therein is recognized based on the header information. Of the additional bits extracted by the

variable length decoding means, the data of the prescribed bit of the additional bits included in the recognized frequency domain is then retrieved. In this way, the above information retrieving apparatus recognizes the frequency domain of the additional bits having the watermark information embedded therein based on the header information. Thereafter, of the additional bits extracted by the variable length decoding means, the above information retrieving apparatus retrieves the data of the prescribed bit of the additional bits included in the recognized frequency domain. This enables the embedded watermark information to be retrieved correctly.

According to yet another aspect of the present invention, a method for embedding watermark information in image data compressed by orthogonal transformation, quantization, run length encoding and variable length encoding includes an extracting step, an embedding step, and a connecting step. In the extracting step, a codeword and an additional bit or bits corresponding to the codeword are extracted from the compressed image data based on a code table. In the embedding step, watermark information is embedded in a prescribed bit of the additional bits extracted by the extracting step. In the connecting step, the additional bits having the watermark information embedded therein by the embedding step are connected with the codeword extracted by

the extracting step to produce a variable length code.

In the above information embedding method, the watermark information is embedded in the prescribed bit of the additional bits, eliminating the need for run length decoding/encoding operations and variable length encoding operation. This simplifies the overall operation as compared to the conventional information embedding method.

As described above, the variable length encoding operation is not required in the above information embedding method. Therefore, unlike the conventional information embedding method, the variable length decoding operation of the compressed image data and the variable length encoding operation of the data having the watermark information embedded therein need not be conducted in a time-sharing manner. Accordingly, the above information embedding method is capable of embedding the watermark information in the compressed image data at a higher speed as compared to the conventional method.

Preferably, the compressed image data having the watermark information embedded therein by the above information embedding method is restored, and the extracting step, the embedding step and the connecting step are conducted again with a reduced number of prescribed bits according to a degree of degradation in quality of the restored image. This suppresses degradation in quality of

the compressed image having the watermark information embedded therein.

Preferably, when part of the watermark information to be embedded fails to be embedded in the above information embedding method, the extracting step, the embedding step and the connecting step are conducted again with an increased number of prescribed bits. This enables all the watermark information to be embedded reliably.

Preferably, the above information embedding method further includes the step of determining whether the codeword extracted by the extracting step is included in the first frequency domain or not. In the embedding step, the watermark information is embedded in the prescribed bit of the additional bits corresponding to the codeword determined as being included in the first frequency domain by the determining step.

The image having watermark information embedded therein normally has degraded quality as compared to the original image. However, the human eyes are sensitive to a change in low frequency components, but insensitive to a change in high frequency components.

The above information embedding method is capable of embedding the watermark information in the additional bits corresponding to the codeword included in the first frequency domain. Accordingly, in order to prevent degradation in

image quality resulting from embedding of the watermark information from being perceived, a relatively high frequency domain is applied as the first frequency domain. In contrast, for the image that cannot be viewed until license fee is paid, the watermark information is intentionally presented to the unauthorized user in a visual form. In this case, a relatively low frequency domain is applied as the first frequency domain. In this way, the watermark information can be embedded in an appropriate frequency domain according to applications and purposes.

Preferably, the compressed image data having the watermark information embedded therein by the above information embedding method is restored, and the extracting step, the embedding step and the connecting step are conducted again with a reduced first frequency domain according to a degree of degradation in quality of the restored image. This suppresses degradation in quality of the compressed image having the watermark information embedded therein.

Preferably, when part of the watermark information to be embedded fails to be embedded in the above information embedding method, the extracting step, the embedding step and the connecting step are conducted again with an increased first frequency domain. This enables all the watermark information to be embedded reliably.

Preferably, the above information embedding method further includes the step of determining whether the additional bits extracted by the extracting step have a prescribed bit length or not. In the embedding step, the watermark information is embedded in the prescribed bit of the additional bits determined as having the prescribed bit length by the determining step.

The number of codewords included in the compressed image data varies between individual images. If a relatively large amount of data is to be embedded as the watermark information, the watermark information must be embedded in the additional bits corresponding to all the codewords included in the compressed image data. However, if a relatively small amount of data is to be embedded as the watermark information, the watermark information need not necessarily be embedded in the additional bits corresponding to all the codewords. In other words, the watermark information need only be embedded in the additional bit(s) corresponding to one or more of the codewords. Degradation in image quality is less likely to be perceived when the watermark information is embedded only in the additional bit(s) corresponding to a less frequently occurring codeword (i.e., a codeword that is included in the compressed image data at a lower rate) than when the watermark information is embedded only in the additional bit(s) corresponding to a frequently occurring codeword (i.e.,

a codeword that is included in the compressed image data at a higher rate).

Normally, a quantized coefficient having a greater value occurs less frequently. Moreover, a greater group number is assigned to a greater quantized coefficient (i.e., a less frequently occurring quantized coefficient). Moreover, a greater additional-bit length is assigned to a greater group number. Accordingly, a greater additional-bit length is assigned to a less frequently occurring quantized coefficient. Moreover, a greater codeword length (code length) is assigned to a greater group number. In other words, a less frequently occurring codeword (i.e., a codeword that is included in the compressed image data at a lower rate) corresponds to a greater group number and a greater additional-bit length.

In the above information embedding method, the watermark information is embedded in the additional bits having a prescribed bit length. Accordingly, when a relatively small amount of data is to be embedded as the watermark information, the watermark information is embedded in the additional bits having a relatively long bit length (i.e., less frequently occurring bits). In this case, the locations where the watermark information is embedded are dispersed on the screen. As a result, degradation in image quality is less likely to be perceived. In this way, the watermark information can be embedded in the additional bits having an appropriate bit

length according to applications and purposes.

Preferably, the compressed image data having the watermark information embedded therein by the above information embedding method is restored, and the extracting step, the embedding step and the connecting step are conducted again with a reduced range of the prescribed bit length according to a degree of degradation in quality of the restored image. This suppresses degradation in quality of the compressed image having the watermark information embedded therein.

Preferably, when part of the watermark information to be embedded fails to be embedded in the above information embedding method, the extracting step, the embedding step and the connecting step are conducted again with an increased range of the prescribed bit length. This enables all the watermark information to be embedded reliably.

Preferably, the above information embedding method further includes the step of determining whether a color component of the codeword extracted by the extracting step is a prescribed color component or not. In the embedding step, the watermark information is embedded in the prescribed bit of the additional bits corresponding to the codeword determined as being the prescribed color component by the determining step.

Normally, the image having the watermark information

embedded therein has degraded quality as compared to the original image. However, the human eyes are sensitive to a change in luminance component, but insensitive to a change in chrominance component.

The above information embedding method is capable of embedding watermark information in the additional bit(s) corresponding to the codeword of the prescribed color component. For example, in order to prevent degradation in image quality resulting from embedding of the watermark information from being perceived, watermark information is embedded in the additional bit(s) corresponding to the codeword of the chrominance component. This suppresses the influence of degradation in image quality. In this way, the watermark information can be embedded in the additional bit(s) corresponding to the codeword of an appropriate color component according to applications and purposes.

Preferably, the compressed image data having the watermark information embedded therein by the above information embedding method is restored, and the extracting step, the embedding step and the connecting step are conducted again with a different prescribed color component according to a degree of degradation in quality of the restored image. This suppresses degradation in quality of the compressed image having the watermark information embedded therein.

Preferably, preprocessing of the extracting step includes the steps of extracting a codeword from the compressed image data based on the code table, and counting the number of extracted codewords.

The above information embedding method makes it possible to know the number of codewords included in the compressed image data in advance.

Preferably, the preprocessing further includes the step of designating the prescribed bit for embedding the watermark information, based on the number of codewords counted by the counting step.

In the above information embedding method, the prescribed bit for embedding the watermark information is designated based on the number of codewords, and the watermark information is embedded in the designated bit. This prevents the embedding operation from being conducted again. Moreover, this enables the watermark information to be embedded uniformly so as to prevent degradation in image quality from being perceived as much as possible.

Preferably, preprocessing of the extracting step includes the steps of extracting a codeword from the compressed image data based on the code table, determining whether the extracted codeword is included in a second frequency domain or not, and counting the number of codewords determined as being included in the second frequency domain.

The above information embedding method makes it possible to know in advance the number of codewords included in the second frequency domain out of the codewords included in the compressed image data.

Preferably, the preprocessing further includes the step of designating the first frequency domain based on the number of codewords counted by the counting step.

In the above information embedding method, the first frequency domain is designated based on the number of codewords counted by the counting step, and the watermark information is embedded in the prescribed bit of the additional bit(s) corresponding to the codeword included in the designated first frequency domain. This prevents the embedding operation from being conducted again.

Preferably, the above information embedding method further includes a multiplexing step. In the multiplexing step, header information is multiplexed with the variable length code produced by the connecting step. The header information indicates which of the additional bits has the watermark information embedded therein.

In the above information embedding method, the header information that indicates which of the additional bits has the watermark information embedded therein is multiplexed. Accordingly, when the image is restored, the embedded watermark information can be correctly retrieved by analyzing

the header information.

Preferably, the above information embedding method further includes a multiplexing step. In the multiplexing step, header information is multiplexed with the variable length code produced by the connecting step. The header information indicates a frequency domain of the additional bit having the watermark information embedded therein by the embedding step.

In the above information embedding method, the header information that indicates a frequency domain of the additional bit having the watermark information embedded therein is multiplexed. Accordingly, when the image is restored, the embedded watermark information can be correctly retrieved by analyzing the header information.

According to a further aspect of the present invention, a method for retrieving watermark information from compressed image data having watermark information embedded therein by the above information embedding method includes a recognizing step, an extracting step and a retrieving step. In the recognizing step, the prescribed bit having the watermark information embedded therein is recognized based on the header information. In the extracting step, an additional bit or bits are extracted from the compressed image data based on a code table. In the retrieving step, data of the prescribed bit recognized by the recognizing step is

retrieved from the additional bits extracted by the extracting step.

In the above information retrieving method, the watermark information is retrieved from the compressed image data having the watermark information embedded therein by the above information embedding method. This compressed image data has header information multiplexed therein. The header information indicates which of the additional bits has the watermark information embedded therein. The bit having the watermark information embedded therein is recognized based on the header information. The data of the recognized bit is then retrieved from the additional bits extracted by the extracting step. In this way, in the above information retrieving method, the prescribed bit having the watermark information embedded therein is recognized based on the header information, and the data of the recognized prescribed bit is retrieved from the additional bits extracted by the extracting step. This enables the embedded watermark information to be retrieved correctly.

According to a still further aspect of the present invention, a method for retrieving watermark information from compressed image data having watermark information embedded therein by the above information embedding method includes a recognizing step, an extracting step and a retrieving step. In the recognizing step, a frequency domain of an additional

bit having the watermark information embedded therein is recognized based on the header information. In the extracting step, an additional bit or bits are extracted from the compressed image data based on a code table. In the retrieving step, data of the prescribed bit of the additional bits extracted by the extracting step is retrieved when the extracted additional bits are included in the frequency domain recognized by the recognizing step.

In the above information retrieving method, watermark information is retrieved from the compressed image data having the watermark information embedded by the above information embedding method. This compressed image data has header information multiplexed therein. The header information indicates a frequency domain of an additional bit having the watermark information embedded therein. The frequency domain of the additional bit having the watermark information embedded therein is recognized based on the header information. Of the additional bits extracted by the extracting step, the data of the prescribed bit of the additional bits included in the recognized frequency domain is then retrieved. In this way, in the above information retrieving method, the frequency domain of the additional bits having the watermark information embedded therein is recognized based on the header information. Thereafter, of the additional bits extracted by the extracting step, the

data of the prescribed bit of the additional bits included in the recognized frequency domain is retrieved. This enables the embedded watermark information to be retrieved correctly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing the overall structure of an information embedding apparatus according to a first embodiment of the present invention;

FIG. **2** shows an original image divided into a plurality of blocks;

FIG. **3** shows DCT coefficients obtained by two-dimensional DCT;

FIG. **4** shows the correspondence between an effective coefficient, a group number, and the number of additional bits;

FIG. **5** shows the correspondence between additional bits and an effective coefficient in a group of group No. 4;

FIG. **6** shows an example of a code table showing the correspondence between a run/group number and a codeword;

FIG. **7** is a flowchart illustrating operation of embedding watermark information by the information embedding apparatus of FIG. **1**;

FIG. **8** shows an example in which the lower two of the additional bits are designated for embedding watermark information;

FIG. **9** shows an example of variable length codes that are sequentially applied to a variable length decoding section;

FIG. **10** illustrates operation of connecting a codeword with additional bits;

FIG. **11** is a block diagram showing the overall structure of an information embedding apparatus according to a second embodiment of the present invention;

FIG. **12** is a flowchart illustrating operation of embedding watermark information by the information embedding apparatus of FIG. **11**;

FIG. **13** shows an example of domain designation information;

FIG. **14** shows an example of variable length codes that are sequentially applied to a variable length decoding section in FIG. **11**;

FIG. **15** shows a codeword, codeword length, additional bits, additional-bit length and a run/group number that are obtained for each variable length code in FIG. **14**;

FIG. **16** is a block diagram showing the overall structure of an information embedding apparatus according to a third embodiment of the present invention;

FIG. **17** is a flowchart illustrating operation of embedding watermark information by the information embedding apparatus in FIG. **16**;

FIG. **18** shows an example of additional-bit length designation information;

FIG. **19** is a block diagram showing the overall structure of an information embedding apparatus according to a fourth embodiment of the present invention;

FIG. **20** is a flowchart illustrating operation of embedding watermark information by the information embedding apparatus in FIG. **19**;

FIG. **21** shows an example of color component designation information;

FIG. **22** is a block diagram showing the overall structure of an information embedding apparatus according to a fifth embodiment of the present invention;

FIG. **23** is a flowchart illustrating operation of embedding watermark information by the information embedding apparatus in FIG. **22**;

FIG. **24** is a block diagram showing the overall structure of an information embedding apparatus according to a sixth embodiment of the present invention;

FIG. **25** is a flowchart illustrating operation of embedding watermark information by the information embedding apparatus in FIG. **24**;

FIG. **26** is a flowchart illustrating a method for embedding watermark information according to a seventh embodiment of the present invention;

FIG. **27** shows the structure of bit stream data;

FIG. **28** is a flowchart illustrating a method for retrieving watermark information according to the seventh embodiment of the present invention;

FIG. **29** is a flowchart illustrating a method for embedding watermark information according to an eighth embodiment of the present invention;

FIG. **30** is a flowchart illustrating a method for retrieving watermark information according to the eighth embodiment of the present invention; and

FIG. **31** is a block diagram showing the overall structure of a conventional information embedding apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be described in detail in conjunction with the accompanying drawings. Note that the same or corresponding portions are denoted with the same reference numerals and characters throughout the figures, and description thereof will not be repeated.

(First Embodiment)

[Overall structure]

FIG. **1** is a block diagram showing the overall structure of an information embedding apparatus according to the first embodiment of the present invention. The information

embedding apparatus of FIG. **1** is an apparatus for embedding information such as copyright information and sound information (watermark information) in compressed image data. The information embedding apparatus includes a variable length decoding section **10**, a code table **11**, an additional-bit register **12**, an additional-bit length register **13**, a codeword register **14**, a codeword length register **15**, an embedding section **16**, and a data connecting section **17**.

The variable length decoding section **10** extracts a codeword **CODE** and additional bits **ADBIT** corresponding to the codeword **CODE** from the compressed image data with reference to the code table **11**. The variable length decoding section **10** also outputs a codeword length **L** and an additional-bit length **M**. The codeword length **L** indicates the length of the codeword **CODE**, and the additional-bit length **M** indicates the length of the additional bits **ADBIT**. The code table **11** indicates the correspondence between a run/group number combination and a codeword. The additional-bit register **12** is an MR-bit register that temporarily stores the additional bits **ADBIT** extracted by the variable length decoding section **10**. The additional-bit length register **13** temporarily stores the additional-bit length **M** from the variable length decoding section **10**. The codeword register **14** is an LR-bit register that temporarily stores the codeword **CODE** extracted by the variable length decoding section **10**. The codeword length

register **15** temporarily stores the codeword length **L** from the variable length decoding section **10**. The embedding section **16** embeds watermark information in a bit(s) of the additional bits stored in the additional-bit register **12** according to bit designation information. The data connecting section **17** connects the additional bits having the watermark information embedded therein with the codeword from the codeword register **14** to produce a variable length code.

[Compressed image data]

Hereinafter, compressed image data in which watermark information is to be embedded by the information embedding apparatus of FIG. **1** will be described. This compressed image data is the image data compressed in a JPEG format. The original image is compressed as follows:

(1) First, as shown in FIG. **2**, the original image data is divided into a plurality of blocks **BK00** to **BKhv**. Each block **BKhv** (where h, v is a positive integer) is formed from 8-by-8 pixels. Each block **BKhv** is subjected to the following operations (2) to (6).

(2) Color space transformation

Color components of the image data in the block **BKhv** are transformed from three-primary-color components (R, G, B) into a luminance component and chrominance components (Y, U, V).

(3) DCT (Discrete Cosine Transform)

After the color space transformation, the resultant image data in the block **BKhv** is subjected to two-dimensional DCT. As a result, DCT coefficients **C1** to **C64** are obtained as shown in FIG. **3**.

(4) Quantization

The DCT coefficients **C1** to **C64** are quantized based on the step size of a quantization table (not shown).

(5) Run length encoding

The DCT coefficients thus quantized are run-length-encoded in order of zigzag scan (in order of frequency), that is, from the DCT coefficient **C1** to the DCT coefficient **C64** as shown in the arrows in FIG. **3**. The run length encoding operation is conducted as follows: first, the quantized DCT coefficients are encoded into a run indicating the number of successive coefficients equal to zero, and the following non-zero coefficient (effective coefficient). Thereafter, a group number and an additional bit(s) are assigned to the effective coefficients. FIG. **4** shows the correspondence between the effective coefficient, the group number and the number of additional bits. The effective coefficients **Dq** are grouped as shown in FIG. **4**. Group No. **SSSS** indicates the group of the effective coefficients **Dq**. An additional bit(s) is assigned to each group in order to specify each effective coefficient in that group. The number of additional bits assigned to each group is equal to the group number of that

group.

For example, as shown in FIG. **4**, the effective coefficient **Dq** having a value "+8" belongs to a group of group No. 4. Accordingly, "4" is assigned as group No. **SSSS** of that effective coefficient **Dq**. Since the group of group No. 4 includes sixteen effective coefficients **Dq**. Therefore, four additional bits are required in order to specify each effective coefficient in the same group (SSSS = 4). As shown in FIG. **5**, the additional-bit values "0000", "0001", …, "1111" are respectively assigned to the effective coefficients in the same group (SSSS = 4) in ascending order (i.e., from -15 to +15). The effective coefficient **Dq** having a value "+8" is the ninth smallest coefficient in the group of group No. 4. Accordingly, an additional-bit value "1000" is assigned thereto.

(6) Variable length encoding

Codewords are respectively assigned to run/group number combinations based on the code table as shown in FIG. **6**. The additional bit(s) is connected right after the assigned codeword to produce a variable length code.

For example, provided that the run/group number combination is 2/4 and the additional bits are "1100", a 12-bit codeword "111111110100" is assigned as shown in FIG. **6**. The additional bits "1100" are connected right after the 12-bit codeword to produce a 16-bit variable length code

"1111111101001100".

Every block **BKhv** is subjected to the above operations (2) to (6). The compressed image data is thus produced.

[Operation of embedding watermark information]

Hereinafter, operation of embedding watermark information by the information embedding apparatus of FIG. **1** will be described with reference to the flowchart of FIG. **7**.

First, in step **ST701**, bit designation information is applied to the embedding section **16**. The bit designation information designates one or more bits (MJ bits) of the M additional bits as bits for embedding the watermark information. FIG. **8** shows an example in which the lower two of the additional bits **ADBIT** are designated for embedding the watermark information. The bit position and the number of bits are not limited to this, and any bit position and any number of bits can be designated. However, it should be noted that, if an upper bit(s) or a plurality of lower bits are designated, embedding the watermark information therein would significantly vary the additional-bit value. This results in significant degradation in quality of the restored (decompressed) image.

Thereafter, in step **ST702**, variable length codes included in the image data compressed in a JPEG format are sequentially applied to the variable length decoding section **10**. It is now assumed that the variable length codes as

shown in FIG. **9** are applied.

In step **ST703**, the variable length decoding section **10** extracts a codeword **CODE** and an additional bit(s) **ADBIT** following the codeword **CODE** with reference to the code table **11** shown in FIG. **6**. The variable length decoding section **10** outputs the bit length (codeword length) **L** of the extracted codeword **CODE** and the bit length (additional-bit length) **M** of the extracted additional bits **ADBIT**. The codeword **CODE** and the additional bits **ADBIT** extracted by the variable length decoding section **10** are temporarily stored in the codeword register **14** and the additional-bit register **12**, respectively. The codeword register **14** is an LR-bit register, and the additional-bit register **12** is an MR-bit register. The codeword length **L** is temporarily stored in the codeword length register **15**. The additional-bit length **M** is temporarily stored in the additional-bit length register **13**. It is herein assumed that the bit width **LR** of the codeword register **14** is 16 (= the maximum codeword length), and the bit width **MR** of the additional-bit register **12** is 12 (= the maximum additional-bit length).

Hereinafter, operation in step **ST703** will be specifically described for the variable length code (16 bits) shown in FIG. **9**.

In FIG. **9**, the first bit string "111111110100" matches the bit string of the codeword corresponding to run/group

number = 2/4 in the code table **12** of FIG. **6**. Accordingly, "111111110100" (12 bits) is extracted as codeword **CODE**. The codeword **CODE** thus extracted is extended to a 16-bit string "0000111111110100" before being stored in the codeword register **14**. In other words, the values "0" are stored in the upper four bits of the 16-bit codeword register **14**. Although the codeword **CODE** is herein extended with the values "0", any value may be used to extend the codeword **CODE**. Alternatively, only the 12-bit codeword "111111110100" may be stored in the 16-bit codeword register. In other words, nothing may be stored in the upper four bits of the 16-bit codeword register **14**.

Since the codeword length **L** is 12 bits, the value "12" is stored in the codeword length register **15**. Since the group number SSSS of the extracted codeword **CODE** is four, the number of additional bits for this codeword **CODE** is four (see FIG. **4**). Accordingly, the four bits "1100" right after the codeword "111111110100" are extracted as additional bits **ADBIT**. The additional bits **ADBIT** thus extracted are extended to a 12-bit string "000000001100" before being stored in the additional-bit register **12**. In other words, the values "0" are stored in the upper eight bits of the 12-bit additional-bit register **12**. Note that, like the codeword register **14**, any value may be stored in the remaining upper bits of the additional-bit register **12**. Alternatively, nothing may be

stored in these upper bits. Since the additional bits **ADBIT** are "1100", the value "4" is stored in the additional-bit length register **13**.

In this way, the following result is obtained:

Codeword **CODE** = "000011111110100";

Additional bits **ADBIT** = "000000001100";

Codeword length **L** = 12; and

Additional-bit length **M** = 4.

Thereafter, in step **ST704**, the embedding section **16** embeds watermark information in the output of the 12-bit (MR-bit) additional-bit register **12** according to the bit designation information. The watermark information is copyright information, sound information and the like. For example, when the lower two bits are designated for embedding the watermark information as shown in FIG. **8**, 2-bit watermark information is embedded in the lower two bits of the output "000000001100" of the 12-bit additional-bit register **12**. In other words, the lower two of the additional bits are replaced with the 2-bit watermark information. Provided that the watermark information to be embedded is "11", the resultant additional-bit value is "000000001111".

In step **ST705**, the data connecting section **17** connects the additional bits from the embedding section **16** with the codeword from the codeword register **14**. Hereinafter, this operation will be described specifically. First, as shown in

FIG. **10**, the bit string "111111110100" designated by the value **L** (in this example, 12) of the codeword length register **15** is extracted from the lower bits of the LR-bit (in this example, 16-bit) codeword "0000111111110100". Moreover, the bit string "1111" designated by the value **M** (in this example, 4) of the additional-bit length register **13** is extracted from the lower bits of the MR (in this example, 12) additional bits "000000001111" having the watermark embedded therein. The M additional bits (i.e., the bit string "1111") are connected right after the L-bit codeword (i.e., the bit string "111111110100"). The variable length code "1111111101001111" is thus produced.

As has been described above, a variable length code having watermark information embedded therein is produced by replacing an additional bit(s) designated by the bit designation information with the watermark information. Every variable length code included in the compressed image data is subjected to steps **ST703** to **ST705**. In this way, compressed image data having watermark information embedded therein is obtained.

Thereafter, in step **ST706**, the compressed image having the watermark information embedded therein is restored (decompressed).

In step **ST707**, quality of the restored image is evaluated. If the image quality is not acceptable (NG in

step **ST707**), the process returns to step **ST701**. In this case, bit designation information designating a reduced number of bits for embedding the watermark information is applied to the embedding section **16**. Thereafter, steps **ST702** to **ST706** are conducted again.

If the image quality is acceptable (OK in step **ST707**), the process proceeds to step **ST708**. In step **ST708**, whether the watermark information to be embedded has been completely embedded or not is determined. If YES in step **ST708**, the process is completed. If NO in step **ST708** (i.e., if it is determined that part of the watermark information has not been embedded), the process returns to step **S701**. In this case, bit designation information designating an increased number of bits for embedding the watermark information is applied to the embedding section **16**. Thereafter, steps **ST702** to **ST707** are conducted again.

[Effects]

The information embedding apparatus of the first embodiment extracts additional bits **ADBIT** from the compressed image data, and embeds the watermark information in one or more bits of the extracted additional bits **ADBIT** according to the bit designation information. Accordingly, unlike the conventional information embedding apparatus that embeds watermark information in a prescribed bit of a quantized coefficient (e.g., DCT coefficient), the information

embedding apparatus of the first embodiment does not require the run-length decoding operation for extracting a quantized coefficient. Moreover, since the watermark information is embedded in one or more bits of the additional bits **ADBIT** according to the bit designation information, the codeword and the additional-bit length will not change before and after embedding the watermark information. Accordingly, unlike the conventional information embedding apparatus, the information embedding apparatus of the first embodiment requires neither run length encoding operation nor variable length encoding operation after embedding the watermark information.

As described above, since the information embedding apparatus of the first embodiment embeds the watermark information in a prescribed bit(s) of the additional bits, it requires neither run-length decoding/encoding operations nor variable length encoding operation. This simplifies the overall structure as compared to the conventional information embedding apparatus.

Moreover, since the variable length encoding operation is not required, the variable length decoding operation of the compressed image data and the variable length encoding operation of the data having the watermark information embedded therein need not be conducted in a time-sharing manner. Accordingly, the information embedding apparatus of

the first embodiment is capable of embedding the watermark information in the compressed image data at a higher speed as compared to the conventional apparatus. This enables high-speed processing in the low-frequency operation, allowing for reduced power consumption.

Moreover, the compressed image having the watermark information embedded therein is restored, and the quality of the restored image is evaluated (step **ST707**). If the quality is not acceptable, the embedding operation is conducted again with a reduced number of bits designated for embedding the watermark information. This suppresses degradation in quality of the compressed image having the watermark information embedded therein.

Moreover, whether the watermark information to be embedded has been completely embedded or not is determined (step **ST708**). If part of the watermark information has not been embedded, the embedding operation is conducted again with an increased number of bits designated for embedding the watermark information. This enables all the embedding information to be embedded reliably.

Although the watermark information is herein embedded in the image data compressed in a JPEG format, the same effects can be obtained even when the watermark information is embedded in the image data compressed in an MPEG format.

Moreover, the information embedding apparatus of the

first embodiment does not necessarily require hardware configuration, but may be implemented by software.

(Second Embodiment)

[Overall structure]

FIG. **11** is a block diagram showing the overall structure of an information embedding apparatus according to the second embodiment of the present invention. Referring to FIG. **11**, this information embedding apparatus further includes a frequency domain determining section **20** in addition to the components of the information embedding apparatus of FIG. **1**. The frequency domain determining section **20** outputs an active enable signal **ENB** to the embedding section **16** when the codeword **CODE** extracted by the variable length decoding section **10** is included in the domain designated by domain designation information. Otherwise, the frequency domain determining section **20** outputs an inactive enable signal **ENB** to the embedding section **16**.

As in the first embodiment, the variable length decoding section **10** extracts a codeword **CODE** and additional bits **ADBIT** and outputs the codeword length **L** and the additional-bit length **M**. In the second embodiment, the variable length decoding section **10** further outputs a run **RRRR** and a group number **SSSS** corresponding to the codeword **CODE** to the frequency domain determining section **20** with reference to the code table **11**. In response to the active enable signal **ENB**

from the frequency domain determining section **20**, the embedding section **16** embeds the watermark information in one or more bits of the additional bits stored in the additional-bit register **12** according to the bit designation information.

[Operation of embedding watermark information]

Hereinafter, operation of embedding watermark information by the above information embedding apparatus will be described with reference to the flowchart of FIG. **12**.

First, in step **ST701**, bit designation information is applied to the embedding section **16**.

Thereafter, in step **ST1601**, domain designation information is applied to the frequency domain determining section **20**. The domain designation information designates the frequency domain of a codeword corresponding to the additional bit(s) in which the watermark information is to be embedded. More specifically, as shown in FIG. **13**, the domain designation information designates the minimum and maximum values **MIN**, **MAX** of the accumulated value of the sum of run **RRRR** and 1 (RRRR + 1). The reason why the domain designation information designates the frequency domain of the codeword is as follows:

In the variable length encoding operation, a codeword is assigned to run/group number combination of the DCT coefficients by using the code table **11**. For example, provided that the run/group number combination is 3/4, a

single codeword is assigned to four DCT coefficients (i.e., three DCT coefficients equal to zero and the following non-zero DCT coefficient). In other words, the sum of the run **RRRR** of a codeword and 1 (RRRR + 1) indicates the number of DCT coefficients corresponding to that codeword. As shown in FIG. **3**, the DCT coefficients are run-length-encoded in order of zigzag scan, that is, in order of frequency. Accordingly, by designating the minimum value **MIN** and the maximum value **MAX** of the accumulated value of (RRRR + 1), the watermark information can be embedded in the additional bits corresponding to the codewords assigned to the MIN^{th} to MAX^{th} DCT coefficients. In FIG. **13**, the watermark information is embedded in the additional bits corresponding to the codewords assigned to the fifth to twentieth DCT coefficients, i.e., the DCT coefficients **C5** to **C20** of FIG. **3**. By designating the minimum and maximum values **MIN, MAX** of the accumulated value of (RRRR + 1) as domain designation information, a desired frequency domain can be designated.

Thereafter, in step **ST702**, the variable length codes included in the image data compressed in a JPEG format are sequentially applied to the variable length decoding section **10**. It is herein assumed that the variable length codes as shown in FIG. **14** are sequentially applied to the variable length decoding section **10**.

In step **ST1602**, the variable length decoding section **10**

extracts the codeword **CODE** and the additional bit(s) **ADBIT** following the codeword **CODE** in the same manner as that in step **ST703** of FIG. **7**, and outputs the codeword length **L** and the additional-bit length **M**. The variable length decoding section **10** also outputs run **RRRR** and group number **SSSS** corresponding to the extracted codeword **CODE** to the frequency domain determining section **20**. In this way, the codeword **CODE**, codeword length **L**, additional bit(s) **ADBIT**, additional-bit length **M**, run/group number (**RRRR/SSSS**) of each variable length code are sequentially obtained.

The codeword **CODE** and the additional bit(s) **ADBIT** extracted by the variable length decoding section **10** are temporarily stored in the codeword register **14** and the additional-bit register **12**, respectively. The codeword length **L** and the additional-bit length **M** are temporarily stored in the codeword length register **15** and the additional-bit length register **13**, respectively.

In step **ST1603**, the frequency domain determining section **20** accumulates the sum of run **RRRR** from the variable length decoding section **10** and 1 (RRRR + 1). The frequency domain determining section **20** determines whether the accumulated value of (RRRR + 1) is included in the range designated by the frequency domain information in FIG. **13**. If YES in step **ST1603** (i.e., if the accumulated value of (RRRR + 1) is included in the range from the minimum value **MIN** to the

maximum value **MAX**), the frequency domain determining section **20** outputs an active enable signal **ENB** to the embedding section **16**. The process then proceeds to step **ST704**. Otherwise, the frequency domain determining section **20** outputs an inactive enable signal **ENB** to the embedding section **16**. In response to the inactive enable signal **ENB**, the embedding section **16** outputs the output of the additional-bit register **12** to the data connecting section **17** without embedding the watermark information. The process then proceeds to step **ST705**. Note that, if the accumulated value of (RRRR + 1) exceeds 64 or the extracted codeword **CODE** is EOB (End of Block), the accumulated value of (RRRR + 1) is reset to zero.

As shown in FIG. **15**, the accumulated value of (RRRR + 1) is equal to 3 for the codeword "11111001". The accumulated value "3" is not within the range designated by the domain designation information. Accordingly, the frequency domain determining section **20** outputs an inactive enable signal **ENB** to the embedding section **16**. In response to the inactive enable signal **ENB**, the embedding section **16** outputs the output of the additional-bit register **12** to the data connecting section **17** without embedding the watermark information. In step **ST705**, the data connecting section **17** connects the additional bits from the embedding section **16** with the codeword from the codeword register **14**. In this way,

the variable length code having no watermark information embedded therein (which is the same as the original variable length code) is obtained.

The accumulated value of (RRRR + 1) is equal to 8 for the following codeword "111011". This accumulated value is within the range designated by the domain designation information. Accordingly, the frequency domain determining section **20** outputs an active enable signal **ENB** to the embedding section **16**. In response to the active enable signal **ENB**, the embedding section **16** embeds the watermark information in the output of the additional-bit register **12** according to the bit designation information in step **ST704**. In step **ST705**, the data connecting section **17** then connects the additional bit from the embedding section **16** with the codeword from the codeword register **14**. In this way, the variable length code having the watermark information embedded therein is obtained.

Similarly, the variable length codes having the watermark information embedded therein are obtained for the codewords "111110111", "1111011", and the variable length code having no watermark information embedded therein is obtained for the codeword "1111010".

Every variable length code included in the compressed image data is subjected to the above operations. The compressed image data having the watermark information

embedded in the frequency domain designated by the domain designation information is thus obtained.

In step **ST706**, the compressed image having the watermark information embedded therein is restored (decompressed).

In step **ST707**, the quality of the restored image is evaluated. If the image quality is not acceptable (NG in step **ST707**), the process returns to step **ST701** or **ST1601**. When the process returns to step **ST701**, bit designation information designating a reduced number of bits for embedding the watermark information is applied to the embedding section **16**. When the process returns to step **ST1601**, domain designation information designating a reduced frequency domain (i.e., designating an increased minimum value **MIN** and/or a reduced maximum value **MAX**) is applied to the frequency domain determining section **20**. Thereafter, steps **ST702** to **ST706** are conducted again.

If the image quality is acceptable (OK in step **ST707**), the process proceeds to step **ST708**. In step **ST708**, whether the watermark information to be embedded has been completely embedded or not is determined. If YES in step **ST708**, the process is completed. If NO in step **ST708** (i.e., if it is determined that part of the watermark information has not been embedded), the process returns to step **ST701** or **ST1601**. When the process returns to step **ST701**, bit designation information designating an increased number of bits for

embedding the watermark information is applied to the embedding section **16**. When the process returns to step **ST1601**, domain designation information designating an increased frequency domain (i.e., designating a reduced minimum value **MIN** and/or an increased maximum value **MAX**) is applied to the frequency domain determining section **20**. Thereafter, steps **ST702** to **ST707** are conducted again.

[Effects]

The image having watermark information embedded therein normally has degraded quality as compared to the original image. However, the human eyes are sensitive to a change in low frequency components, but insensitive to a change in high frequency components.

The information embedding apparatus of the second embodiment is capable of embedding the watermark information in the additional bit(s) corresponding to the codeword included in the frequency domain designated by the domain designation information. For example, in order to prevent degradation in image quality resulting from embedding of the watermark information from being perceived, domain designation information designating a relatively high frequency domain is applied. In contrast, for the image that cannot be viewed until license fee is paid, the watermark information is intentionally presented to the unauthorized user in a visual form. In this case, domain designation

information designating a relatively low frequency domain is applied. In this way, the watermark information can be embedded in an appropriate frequency domain according to applications and purposes.

If the restored image has extremely poor quality, domain designation information designating a reduced frequency domain is applied to the frequency domain determining section **20**, and the embedding operation is conducted again. This suppresses degradation in quality of the compressed image having the watermark information embedded therein.

Moreover, if part of the watermark information to be embedded has not been embedded, domain designation information designating an increased frequency domain is applied to the frequency domain determining section **20**, and the embedding operation is conducted again. This enables all the watermark information to be embedded reliably.

Note that the domain designation information herein designates both minimum and maximum values **MIN**, **MAX** of the accumulated value. Alternatively, the domain designation information may designate either the minimum value **MIN** or the maximum value **MAX**.

Moreover, the same effects as those of the first embodiment can be obtained by the information embedding apparatus of the second embodiment.

The watermark information is herein embedded in the

image data compressed in a JPEG format. However, the same effects can be obtained even when the watermark information is embedded in the image data compressed in an MPEG format.

The information embedding apparatus of the second embodiment does not necessarily require hardware configuration, but may be implemented by software.

(Third Embodiment)

[Overall structure]

FIG. **16** is a block diagram showing the overall structure of an information embedding apparatus according to the third embodiment of the present invention. Referring to FIG. **16**, this information embedding apparatus further includes an additional-bit length determining section **30** in addition to the components of the information embedding apparatus of FIG. **1**. The additional-bit length determining section **30** outputs an active enable signal **ENB** to the embedding section **16** when the additional-bit length **M** from the variable length decoding section **10** is within the range designated by additional-bit length designation information. Otherwise, the additional-bit length determining section **30** outputs an inactive enable signal **ENB** to the embedding section **16**. In response to the active enable signal **ENB**, the embedding section **16** embeds the watermark information in one or more bits of the additional bits stored in the additional-bit register **12** according to bit designation information.

[Operation of embedding watermark information]

Hereinafter, operation of embedding watermark information by the above information embedding apparatus will be described with reference to the flowchart of FIG. **17**.

First, in step **ST701**, bit designation information is applied to the embedding section **16**.

In step **ST1701**, additional-bit length designation information is applied to the additional-bit length determining section **30**. The additional-bit length designation information designates the bit length of the additional bits in which the watermark information is to be embedded. More specifically, as shown in FIG. **18**, the additional-bit length designation information designates the minimum bit length **M(min)** and the maximum bit length **M(max)**.

In step **ST702**, variable length codes included in the image data compressed in a JPEG format are sequentially applied to the variable length decoding section **10**.

In step **ST703**, the variable length decoding section **10** extracts a codeword **CODE** and an additional bit(s) **ADBIT** following the codeword **CODE**, and outputs the codeword length **L** and the additional-bit length **M**. The codeword **CODE** and the additional bit(s) **ADBIT** extracted by the variable length decoding section **10** are temporarily stored in the codeword register **14** and the additional-bit register **12**, respectively. The codeword length **L** and the additional-bit length **M** are

temporarily stored in the codeword length register **15** and the additional-bit length register **13**, respectively.

In step **ST1702**, the additional-bit length determining section **30** determines whether the additional-bit length **M** from the variable length decoding section **10** is included in the range designated by the additional-bit length designation information. If YES in step **ST1702** (i.e., if the additional-bit length **M** is included in the range from the minimum bit length **M(min)** to the maximum bit length **M(max)**), the additional-bit length determining section **30** outputs an active enable signal **ENB** to the embedding section **16**. In response to the active enable signal **ENB**, the embedding section **16** embeds the watermark information in the output of the additional-bit register **12** according to the bit designation information in step **ST704**. In step **ST705**, the data connecting section **17** connects the additional bits from the embedding section **16** with the codeword from the codeword register **14**. In this way, the variable length code having the watermark information embedded therein is obtained. If NO in step **ST1702** (i.e., if the additional-bit length **M** is smaller than the minimum bit length **M(min)** or greater than the maximum bit length **M(max)**), the additional-bit length determining section **30** outputs an inactive enable signal **ENB** to the embedding section **16**. In response to the inactive enable signal **ENB**, the embedding section **16** outputs the

output of the additional-bit register **12** to the data connecting section **17** without embedding the watermark information. In step **ST705**, the data connecting section **17** connects the additional bits from the embedding section **16** with the codeword from the codeword register **14**. In this way, the variable length code having no watermark information embedded therein (which is the same as the original variable length code) is obtained.

Every variable length code included in the compressed image data is subjected to the above operations. Thus, the resultant compressed image has the watermark information embedded according to the additional-bit length designation information.

Thereafter, in step **ST706**, the compressed image having the watermark information embedded therein is restored (decompressed).

In step **ST707**, quality of the restored image is evaluated. If the image quality is not acceptable (NG in step **ST707**), the process returns to step **ST701** or **ST1701**. When the process returns to step **ST701**, bit designation information designating a reduced number of bits for embedding the watermark information is applied to the embedding section **16**. When the process returns to step **ST1701**, additional-bit length designation information designating a reduced range of the additional-bit length

(i.e., designating an increased minimum bit length **M(min)** and/or a reduced maximum bit length **M(max)**) is applied to the additional-bit length determining section **30**. Thereafter, steps **ST702** to **ST706** are conducted again.

If the image quality is acceptable (OK in step **ST707**), the process proceeds to step **ST708**. In step **ST708**, whether the watermark information to be embedded has been completely embedded or not is determined. If YES in step **ST708**, the process is completed. If NO in step **ST708** (i.e., if it is determined that part of the watermark information has not been embedded), the process returns to step **ST701** or **ST1701**. When the process returns to step **ST701**, bit designation information designating an increased number of bits for embedding the watermark information is applied to the embedding section **16**. When the process returns to step **ST1701**, additional-bit length designation information designating an increased range of the additional-bit length (i.e., designating a reduced minimum bit length **M(min)** and/or an increased maximum bit length **M(max)**) is applied to the additional-bit length determining section **30**. Thereafter, steps **ST702** to **ST707** are conducted again.

[Effects]

The number of codewords included in the compressed image data varies between individual images. If a relatively large amount of data is to be embedded as the watermark information,

the watermark information must be embedded in the additional bits corresponding to all the codewords included in the compressed image data. However, if a relatively small amount of data is to be embedded as the watermark information, the watermark information need not necessarily be embedded in the additional bits corresponding to all the codewords. In other words, the watermark information need only be embedded in the additional bit(s) corresponding to one or more of the codewords. Degradation in image quality is less likely to be perceived when the watermark information is embedded only in the additional bit(s) corresponding to a less frequently occurring codeword (i.e., a codeword that is included in the compressed image data at a lower rate) than when the watermark information is embedded only in the additional bit(s) corresponding to a frequently occurring codeword (i.e., a codeword that is included in the compressed image data at a higher rate).

Normally, a quantized DCT coefficient having a greater value occurs less frequently. Moreover, as shown in FIG. **4**, a greater group number **SSSS** is assigned to a greater quantized DCT coefficient (i.e., a less frequently occurring quantized DCT coefficient). Moreover, a greater number of additional bits are assigned to a greater group number **SSSS**. Accordingly, a greater number of additional bits are assigned to a less frequently occurring quantized DCT coefficient. As

shown in FIG. **6**, the code table is normally preset such that a greater codeword length (code length) is assigned to a greater group number **SSSS**. In other words, a less frequently occurring codeword (i.e., a codeword that is included in the compressed image data at a lower rate) corresponds to a greater group number and a greater number of additional bits (a greater bit length).

The information embedding apparatus of the third embodiment embeds the watermark information in the additional bits having a bit length within the range designated by the additional-bit length designation information. Accordingly, when a relatively small amount of data is to be embedded as the watermark information, the watermark information is embedded in the additional bits having a relatively long bit length (i.e., less frequently occurring bits). In this case, the locations where the watermark information is embedded are dispersed on the screen. As a result, degradation in image quality is less likely to be perceived. The watermark information can thus be embedded in the additional bits having an appropriate bit length according to applications and purposes.

If the restored image has extremely poor quality, additional-bit length designation information designating a reduced range of the bit length is applied to the additional-bit length determining section **30**, and the embedding

operation is conducted again. This suppresses degradation in quality of the compressed image having the watermark information embedded therein.

If part of the watermark information to be embedded has not been embedded, additional-bit length designation information designating an increased range of the bit length is applied to the additional-bit length determining section **30**, and the embedding operation is conducted again. This enables all the watermark information to be embedded reliably.

Note that the additional-bit length designation information herein designates both minimum and maximum bit lengths **M(min)**, **M(max)**. Alternatively, the additional-bit length designation information may designate either the minimum bit length **M(min)** or the maximum bit length **M(max)**.

Moreover, the same effects as those of the first embodiment can be obtained by the information embedding apparatus of the third embodiment.

The watermark information is herein embedded in the image data compressed in a JPEG format. However, the same effects can be obtained even when the watermark information is embedded in the image data compressed in an MPEG format.

The information embedding apparatus of the third embodiment does not necessarily require hardware configuration, but may be implemented by software.

(Fourth Embodiment)

[Overall structure]

FIG. **19** is a block diagram showing the overall structure of an information embedding apparatus according to the fourth embodiment of the present invention. The information embedding apparatus of FIG. **19** further includes a color component determining section **40** in addition to the components of the information embedding apparatus of FIG. **1**. The color component determining section **40** outputs an active enable signal **ENB** to the embedding section **16** when color component information **COLOR** extracted by the variable length decoding section **10** matches a color component designated by color component designation information. Otherwise, the color component determining section **40** outputs an inactive enable signal **ENB** to the embedding section **16**.

As in the above embodiments, the variable length decoding section **10** extracts a codeword **CODE** and an additional bit(s) **ADBIT** and outputs the codeword length **L** and the additional-bit length **M**. In the fourth embodiment, the variable length decoding section **10** further extracts the color component information **COLOR** from the compressed image data for output to the color component determining section **40**. The color component information **COLOR** indicates color components (Y, U, V) of a variable length code applied to the variable length decoding section **10**. In response to the active enable signal **ENB** from the color component determining

section **40**, the embedding section **16** embeds watermark information in one or more bits of the additional bits stored in the additional-bit register **12** according to the bit designation information.

[Operation of embedding watermark information]

Hereinafter, operation of embedding watermark information by the above information embedding apparatus will be described with reference to the flowchart of FIG. **20**.

First, in step **ST701**, bit designation information is applied to the embedding section **16**.

In step **ST2001**, color component designation information is applied to the color component determining section **40**. The color component designation information designates a color component or components in which the watermark information is to be embedded. The "color components" refers to a luminance component **Y** and chrominance components **U**, **V**, which are elements of the image data. More specifically, as shown in FIG. **21**, the color component designation information includes designation information **YE** of the luminance component and designation information **UE**, **VE** of the chrominance components. The designation information **YE**, **UE**, **VE** is set to 1 when the watermark information is to be embedded in a corresponding color component. The designation information **YE**, **UE**, **VE** is set to zero when no watermark information is to be embedded in a corresponding color

component. For example, in Fig. **21**, the color component designation information of YE = 0, UE = 1, VE = 1 indicates that no watermark information is to be embedded in the additional bits of the luminance component **Y** and the watermark information is to be embedded only in the additional bits of the chrominance components **U, V.**

In step **ST702,** variable length codes included in the image data compressed in a JPEG format are sequentially applied to the variable length decoding section **10.**

In step **ST2002,** the variable length decoding section **10** extracts a codeword **CODE** and an additional bit(s) **ADBIT** following the codeword **CODE** and outputs the codeword length **L** and the additional-bit length **M** in the same manner as that in step **ST703** in FIG. **7.** The variable length decoding section **10** further extracts the color component information **COLOR** from the compressed image data for output to the color component determining section **40.** The codeword **CODE** and the additional bit(s) **ADBIT** extracted by the variable length decoding section **10** are temporarily stored in the codeword register **14** and the additional-bit register **12,** respectively. The codeword length **L** and the additional-bit length **M** are temporarily stored in the codeword length register **15** and the additional-bit length register **13,** respectively.

In step **ST2003,** the color component determining section **40** compares the color component information **COLOR** from the

variable length decoding section **10** with the color component designation information. If any of the designation information **YE, UE, VE** having a value "1" matches the color component information **COLOR** (OK in step **ST2003**), the color component determining section **40** outputs an active enable signal **ENB** to the embedding section **16.** In response to the active enable signal **ENB,** the embedding section **16** embeds the watermark information in the output of the additional-bit register **12** according to the bit designation information in step **ST704.** In step **ST705,** the data connecting section **17** connects the additional bits from the embedding section **16** with the codeword from the codeword register **14.** In this way, the variable length code having the watermark information embedded therein is obtained.

If none of the designation information **YE, UE, VE** having a value "1" matches the color component information **COLOR** (NG in step **ST2003**), the color component determining section **40** outputs an inactive enable signal **ENB** to the embedding section **16.** In response to the inactive enable signal **ENB,** the embedding section **16** outputs the output of the additional-bit register **12** to the data connecting section **17** without embedding the watermark information. In step **ST705,** the data connecting section **17** connects the additional bits from the embedding section **16** with the codeword from the codeword register **14.** In this way, the variable length code

having no watermark information embedded therein (which is the same as the original variable length code) is obtained.

Every variable length code included in the compressed image data is subjected to the above operations. Thus, the resultant compressed image data has the watermark information embedded in the additional bits corresponding to the codeword of the color component designated by the color component designation information.

In step **ST706**, the compressed image having the watermark information embedded therein is restored (decompressed).

In step **ST707**, quality of the restored image is evaluated. If the image quality is not acceptable (NG in step **ST707**), the process returns to step **ST701** or **ST2001**. When the process returns to step **ST701**, bit designation information designating a reduced number of bits for embedding the watermark information is applied to the embedding section **16**. When the flow returns to step **ST2001**, color component designation information indicating different designation information **YE**, **UE**, **VE** is applied to the color component determination section **40**. For example, the color component designation information (YE = 0, UE = 1, VE = 0) is applied instead of the color component designation information (YE = 1, UE = 0, VE = 0). This is based on the property that "the human eyes are sensitive to a change in luminance component, but insensitive to a change in

chominancecomponent". Thereafter, steps **ST702** to **ST706** are conducted again.

If the quality is acceptable (OK in step **ST707**), the process proceeds to step **ST708.** In step **ST708,** whether the watermark information to be embedded has been completely embedded or not is determined. If YES in step **ST708,** the process is completed. If NO in step **ST708** (i.e., if it is determined that part of the watermark information has not been embedded), the process returns to step **ST701** or **ST2001.** When the process returns to step **ST701,** bit designation information designating an increased number of bits for embedding the watermark information is applied to the embedding section **16.** When the process returns to step **ST2001,** color component designation information designating an increased number of color components for embedding the watermark information is applied to the color component determining section **40.** For example, the color component designation information (YE = 1, UE = 1, VE = 0) is applied instead of the color component designation information (YE = 1, UE = 0, VE = 0). Thereafter, steps **ST702** to **ST707** are conducted again.

[Effects]

Normally, the image having watermark information embedded therein has degraded quality as compared to the original image. However, the human eyes are sensitive to a

change in luminance component, but insensitive to a change in chominancecomponent.

The information embedding apparatus of the fourth embodiment is capable of embedding watermark information in the additional bit(s) corresponding to the codeword of the color component designated by the color component designation information. For example, in order to prevent degradation in image quality resulting from embedding of the watermark information from being perceived, watermark information is embedded in the additional bit(s) corresponding to the codeword of the chominancecomponent. This suppresses the influence of degradation in image quality. In this way, the watermark information can be embedded in the additional bit(s) corresponding to the codeword of an appropriate color component according to applications and purposes.

If the restored image has extremely poor quality, color component designation information indicating different designation information (YE, UE, VE) is applied to the color component determining section **40**, and the embedding operation is conducted again. This suppresses degradation in quality of the compressed image having watermark information embedded therein.

If part of the watermark information has not been embedded, color component designation information designating an increased number of color components for embedding the

watermark information is applied to the color component determining section **40**, and the embedding operation is conducted again. This enables all the watermark information to be embedded reliably.

Note that the same effects as those of the first embodiment can be obtained by the information embedding apparatus of the fourth embodiment.

The watermark information is herein embedded in the image data compressed in a JPEG format. However, the same effects can be obtained even when the watermark information is embedded in the image data compressed in an MPEG format.

The information embedding apparatus of the fourth embodiment does not necessarily require hardware configuration, but may be implemented by software.

(Fifth Embodiment)

[Overall structure]

FIG. **22** is a block diagram showing the overall structure of an information embedding apparatus according to the fifth embodiment of the present invention. The information embedding apparatus of FIG. **22** further includes a codeword counter **50** and a bit designating section **51** in addition to the components of the information embedding apparatus of FIG. **1**. The codeword counter **50** counts the number of codewords **CODE** extracted by the variable length decoding section **10**. The bit designating section **51** produces bit designation

information based on the number of codewords counted by the codeword counter **50** and the amount of watermark information to be embedded, and outputs the bit designation information to the embedding section **16**.

[Preprocessing]

Hereinafter, operation of embedding watermark information by the information embedding apparatus of FIG. **22** will be described with reference to FIG. **23**. The preprocessing (**ST2301** to **ST2304**) that is different from the processing in the flowchart of FIG. **7** will be described below.

First, in step **ST2301**, variable length codes included in the image data compressed in a JPEG format are sequentially applied to the variable length decoding section **10** in the same manner as that in step **ST702** of FIG. **7**.

In step **ST2302**, the variable length decoding section **10** sequentially extracts codewords **CODE** in the same manner as that in step **ST703** of FIG. **7**.

In step **ST2303**, the codeword counter **50** counts the number of codewords extracted by the variable length decoding section **10**. After counting all the codewords included in the compressed image data, the codeword counter **50** outputs the number of codewords **CODE(MAX)** to the bit designating section **51**.

In step **ST2304**, the bit designating section **51** produces bit designation information based on the number of codewords

CODE(MAX) included in the compressed image data and the data amount of watermark information to be embedded **DINFO**, and outputs the bit designation information to the embedding section **16**. This operation will now be described specifically.

(1) For DINFO < CODE(MAX)

When the data amount of watermark information to be embedded is smaller than the number of codewords included in the compressed image data, the watermark information need only be embedded in one bit of an additional-bit value. Accordingly, the bit designating section **51** produces bit designation information that designates one bit of an additional-bit value for embedding the watermark information.

(2) For DINFO > CODE(MAX)

When the data amount of watermark information to be embedded is larger than the number of codewords included in the compressed image data, designating only one bit of an additional-bit value is not enough to embed all the watermark information. More specifically, if one bit of an additional-bit value is designated as a bit for embedding the watermark information, part of the watermark information fails to be embedded, and therefore the embedding operation is conducted again. Accordingly, a plurality of bits in an additional-bit value must be designated as bits for embedding the watermark information. The bit designating section **51** obtains an

integer **MJ** satisfying the following expression:

$$MJ > DINFO/CODE(MAX).$$

The bit designating section **51** then produces bit designation information that designates MJ additional bits for embedding the watermark information. It is desirable to select the smallest possible value **MJ** from those satisfying the above condition. This enables the watermark information to be embedded uniformly on the screen. As a result, degradation in image quality becomes less likely to be perceived as compared to the case where the watermark information is embedded intensively in a part of the screen (e.g., the watermark information is embedded only in the upper half of the screen).

After such preprocessing, the variable length codes are applied again (step **ST702**), and the embedding operation is conducted sequentially (steps **ST703** to **ST708**).

[Effects]

As has been described above, the information embedding apparatus of the fifth embodiment produces bit designation information based on the number of codewords **CODE(MAX)** included in the compressed image data and the data amount of watermark information to be embedded **DINFO**. This prevents the embedding operation from being conducted again. Moreover, this enables the watermark information to be embedded uniformly so as to prevent degradation in image quality from

being perceived as much as possible.

Note that the same effects as those of the first embodiment can be obtained by the information embedding apparatus of the fifth embodiment.

The watermark information is herein embedded in the image data compressed in a JPEG format. However, the same effects can be obtained even when the watermark information is embedded in the image data compressed in an MPEG format.

The information embedding apparatus of the fifth embodiment does not necessarily require hardware configuration, but may be implemented by software.

(Sixth Embodiment)

[Overall structure]

FIG. **24** is a block diagram showing the overall structure of an information embedding apparatus according to the sixth embodiment of the present invention. The information embedding apparatus of FIG. **24** further includes a domain codeword counter **60** and a frequency domain designating section **61** in addition to the components of the information embedding apparatus of FIG. **11**. The domain codeword counter **60** counts the number of active enable signals **ENB** output from the frequency domain determining section **20**. The frequency domain designating section **61** produces domain designation information based on the number of enable signals **ENB** counted by the domain codeword counter **60** for output to the frequency

domain determining section **20**.

[Preprocessing]

Hereinafter, operation of embedding watermark information by the information embedding apparatus of FIG. **24** will be described with reference to FIG. **25**. The preprocessing (steps **ST2501** to **ST2506**) that is different from the processing in the flowchart of FIG. **12** will be described below.

In step **ST2501**, bit designation information is applied to the embedding section **16** in the same manner as that in step **ST701** of FIG. **12**. In step **ST2502**, the frequency domain designating section **61** produces domain designation information designating a prescribed domain (second frequency domain) for output to the frequency domain determining section **20**. This domain designation information is the same as that shown in FIG. **13**.

In step **ST2503**, variable length codes included in the image data compressed in a JPEG format are sequentially applied to the variable length decoding section **10** in the same manner as that in step **ST702** of FIG. **12**.

In step **ST2504**, the variable length decoding section **10** sequentially extracts codewords **CODE** and outputs run **RRRR** and group number **SSSS** corresponding to the extracted codeword **CODE** to the frequency domain determining section **20** in the same manner as that in step **ST1602** of FIG. **12**.

In step **ST2505**, the frequency domain determining section **20** accumulates the sum of the run **RRRR** from the variable length decoding section **10** and 1 (RRRR + 1) in the same manner as that in step **ST1603** in FIG. **12**. It is then determined whether the accumulated value of (RRRR + 1) is within the range designated by the domain designation information or not. If it is determined that the accumulated value is within the range designated by the domain designation information, the frequency domain designating section **20** outputs an active enable signal **ENB** to the embedding section **16**. Otherwise, the frequency domain designating section **20** outputs an inactive enable signal **ENB** to the embedding section **16**.

The domain codeword counter **60** counts the number of active enable signals **ENB** output from the frequency domain determining section **20**. The number of codewords in the domain designated by the domain designation information (the second frequency domain) is thus counted. After counting all the codewords included in the compressed image data, the domain codeword counter **60** outputs a count value **CODE(ENB)** to the frequency domain designating section **61**. This count value **CODE(ENB)** indicates the number of codewords included in the second frequency domain out of the codewords included in the compressed image data.

In step **ST2506**, the frequency domain designating section

61 first calculates the maximum value **DINFO(MAX)** of the data amount of watermark information that can be embedded in the compressed image data. The maximum value **DINFO(MAX)** is calculated by the following equation:

DINFO(MAX) = MJ × CODE(ENB)

where MJ is the number of bits in which the watermark information is to be embedded in a single additional-bit value.

The frequency domain designating section **61** then compares the data amount of watermark information to be embedded, **DINFO**, with the maximum value **DINFO(MAX)**, and conducts the following operation based on the comparison result:

(1) For DINFO < DINFO(MAX)

The process returns to step **ST2502**, and domain designation information designating a reduced frequency domain is applied to the frequency domain determining section **20.** Thereafter, steps **ST2503** to **ST2506** are conducted again.

(2) For DINFO > DINFO(MAX)

The process returns to step **ST2502**, and domain designation information designating an increased frequency domain is applied to the frequency domain determining section **20.** Thereafter, steps **ST2503** to **ST2506** are conducted again.

(3) For DINFO ≒ DINFO(MAX)

The process proceeds to step **ST702.**

In this way, the domain designation information is adjusted so that the maximum value **DINFO(MAX)** becomes nearly equal to the data amount **DINFO.** Once the domain designation information satisfying DINFO $\fallingdotseq$ DINFO(MAX) (DINFO $\leq$ DINFO(MAX)) is obtained, the embedding operation is conducted in steps **ST702** to **ST708** according to that domain designation information.

[Effects]

As has been described above, the information embedding apparatus of the sixth embodiment conducts the preprocessing (steps **ST2501** to **ST2506**). The domain designation information thus obtained is such that the maximum value **DINFO(MAX)** of the data amount of watermark information that can be embedded in the frequency domain designated by the domain designation information is nearly equal to the data amount of watermark information to be embedded, **DINFO**. This prevents the embedding operation from being conducted again.

The original additional bits (i.e., the additional bits before embedding the watermark information) vary as a result of embedding the watermark information therein. This causes degradation in quality of the restored image. However, the information embedding apparatus of the sixth embodiment sets the frequency domain for embedding the watermark information as small as possible. Accordingly, degradation in quality of the restored image can be minimized.

Note that the same effects as those of the second embodiment can be obtained by the information embedding apparatus of the sixth embodiment.

The watermark information is herein embedded in the image data compressed in a JPEG format. However, the same effects can be obtained even when the watermark information is embedded in the image data compressed in an MPEG format.

The information embedding apparatus of the sixth embodiment does not necessarily require hardware configuration, but may be implemented by software.

(Seventh Embodiment)

[Embedding of watermark information]

FIG. **26** is a flowchart illustrating a method for embedding watermark information according to the seventh embodiment of the present invention. The embedding method of FIG. **26** is characterized by producing header information and multiplexing the header information with a variable length code. The header information indicates which of the additional bits has the watermark information embedded therein. This embedding method will now be described with reference to FIG. **26**.

First, in step **ST2601**, a bit(s) for embedding the watermark information is designated from the additional bits.

In step **ST2602**, the watermark information is embedded in the bit(s) designated in step **ST2601**. The embedding

operation is conducted in the same manner as that described in the first embodiment.

In parallel with step **ST2602**, header information is produced in step **ST2603**. The header information indicates which of the additional bits has the watermark information embedded therein.

In step **ST2604**, the header information produced in step **ST2603** and the variable length code having the watermark information embedded therein in step **ST2602** are multiplexed (i.e., coupled into a bit stream) to produce the bit stream data as shown in FIG. **27**.

[Retrieval of watermark information]

FIG. **28** is a flowchart illustrating a method for retrieving the watermark information from the bit stream data produced by the embedding method of FIG. **26**. This retrieving method will now be described with reference to FIG. **28**.

First, in step **ST2801**, the header information in the bit stream data is analyzed. As described above, the header information indicates which of the additional bits has the watermark information embedded therein.

In step **ST2802**, the bit(s) having the watermark information embedded therein are recognized from the analysis result.

In step **ST2803**, the additional bits are sequentially extracted by the variable length decoding operation. This

variable length decoding operation is the same as step **ST703** of FIG. **7**. The data of the bit(s) recognized in step **ST2802** is retrieved from the extracted additional bits. In this way, the watermark information is retrieved.

[Effects]

As has been described above, in the method for embedding the watermark information according to the seventh embodiment, the header information indicating which of the additional bits has the watermark information embedded therein is multiplexed with the variable length code. In the method for retrieving the watermark information according to the seventh embodiment, the bit(s) having the watermark information embedded therein is recognized based on the header information, and the data of the recognized bit(s) is retrieved from the additional bits extracted by the variable length decoding operation. Accordingly, the embedded watermark information can be retrieved correctly.

(Eighth Embodiment)

[Embedding of watermark information]

FIG. **29** is a flowchart illustrating a method for embedding watermark information according to the eighth embodiment of the present invention. The embedding method of FIG. **29** is characterized by producing header information and multiplexing the header information with a variable length code. The header information indicates the frequency domain

of the additional bit(s) having the watermark information embedded therein. This embedding method will now be described with reference to FIG. **29**.

First, in step **ST2901**, a frequency domain of the additional bit(s) for embedding the watermark information is designated.

In step **ST2902**, the watermark information is embedded in the additional bit(s) in the designated frequency domain. The embedding operation is conducted in the same manner as that described in the second embodiment.

In parallel with step **ST2902**, header information is produced in step **ST2903**. The header information indicates the frequency domain of the additional bit(s) having the watermark information embedded therein.

In step **ST2904**, the header information produced in step **ST2903** and the variable length code having the watermark information embedded therein in step **ST2902** are multiplexed (i.e., coupled into a bit stream) to produce the bit stream data as shown in FIG. **27**.

[Retrieval of watermark information]

FIG. **30** is a flowchart illustrating a method for retrieving the watermark information from the bit stream data produced by the embedding method of FIG. **29**. This retrieving method will now be described with reference to FIG. **30**.

First, in step **ST3001**, the header information in the bit

stream data is analyzed. As described above, the header information indicates the frequency domain of the additional bit(s) having the watermark information embedded therein.

In step **ST3002**, the frequency domain of the additional bit(s) having the watermark information embedded therein is recognized from the analysis result.

In step **ST3003**, the additional bits are sequentially extracted by the variable length decoding operation. Of the extracted additional bits, the data of a prescribed bit(s) in the frequency domain recognized in step **ST3002** is retrieved. The prescribed bit(s) is a bit(s) that is designated in advance as a bit for embedding the watermark information. In this way, the watermark information is retrieved.

[Effects]

As has been described above, in the method for embedding the watermark information according to the eighth embodiment, the header information (information that indicates the frequency domain of the additional bit(s) having the watermark information embedded therein) is multiplexed with the variable length code. In the method for retrieving the watermark information according to the eighth embodiment, the frequency domain of the additional bit(s) having the watermark information embedded therein is recognized based on the header information. Thereafter, of the additional bits extracted by the variable length decoding operation, the

watermark information is retrieved from the additional bit(s) in the frequency domain. Accordingly, the embedded watermark information can be retrieved correctly.